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VELA NETWORK EVALUATION AND AUTOMATIC PROCESSING RESEARCH

QUARTERLY REPORT NO.2

1 JANUARY 1977 TO 31 MARCH 1977

TEXAS INSTRUMENTS INCORPORATED
Equipment Group
Post Office Box 6015
Dallas, Texas 75222

Contract Number: F08606-77-C-0004
Amount of Contract: $560,000
Beginning 1 October 1977
Ending 30 September 1977

Prepared for

AIR FORCE TECHNICAL APPLICATIONS CENTER
Alexandria, Virginia 22314

Sponsored by

ADVANCED RESEARCH PROJECTS AGENCY
Nuclear Monitoring Research Office
ARPA Program Code No. 7F10
ARPA Order No. 2551

4 April 1977

Acknowledgment: This research was supported by the Advanced Research Projects Agency, Nuclear Monitoring Research Office, under Project VELA-UNIFORM, and accomplished under the technical direction of the Air Force Technical Applications Center under Contract Number F08606-77-C-0004.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This second quarterly report summarizes progress under the VELA Network and Automatic Processing Research Program, Contract Number F08606-77-C-0004, during the period 1 January 1977 to 31 March 1977. Work in the following areas is summarized:

- (1) Evaluation of ILPA and SRO data;
- (2) Development of detection methods; → next page

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- (3) Methods of extracting long-period event waveforms;
- (4) Interactive seismic signal processing;
- (5) Determining path corrections and extracting source parameters from long-period data.

TABLE OF CONTENTS

SECTION I
INTRODUCTION AND SUMMARY

This second quarterly report summarizes the progress made during the period between 1 January 1977 to 31 March 1977 in the VELA Network Evaluation and Automatic Processing Research program being carried out by Texas Instruments Incorporated at the Seismic Data Analysis Center (SDAC) in Alexandria, Virginia. The five program tasks are:

- Evaluate the performance of the Iranian Long-Period Array (ILPA) and the Seismic Research Observatories (SRO).
- Develop advanced methods for detecting seismic events and evaluate the event detection capability of postulated networks of seismic detectors.
- Extract seismic event waveforms given the location and origin time of an event.
- Develop and demonstrate function processes for interactive signal processing; standardize and automate the processing functions; also demonstrate their feasibility for the graphics processing of events.
- Compute instrument and path corrected spectra of a network of long-period seismic sensors and estimate seismic source parameters.

The Research Objective Plan drawn up and approved for performing these tasks is approximately on schedule. During this quarter we had a program review of current progress on the above items, which also included a summary of last years work.

For both the ILPA and SRO data evaluations, work was concentrated in the following areas:

- Complete a data base sufficient for evaluation of the stations and networks. The data base will be expanded when the National Earthquake Information Service (NEIS) lists are available.
- Maintain data preparation software which is primarily the conversion of edit and beamform programs to the Terminal Support (TS) system.
- Complete software to filter and plot data.
- Perform the routine signal processing and analysis needed to evaluate each station separately and to evaluate all stations as a network designed to locate and measure earthquakes and presumed explosions.

To develop advanced methods for detecting seismic events, five research tasks are being pursued. These are as follows:

- Determine the feasibility of using frequency dependent detection algorithms.
- Perfect and test methods for improving an automatic detector's capability to accurately time the arrival of seismic events.
- Determine the feasibility of using an adaptive beamformer to detect weak signals generated by seismic events.
- Develop an automatic method to associate the detections of an event received at a sub-set of seismic stations and to predict the arrival times of event phases at all stations of the network.
- Improve the accuracy of estimating a seismic network's capability to detect events of a given magnitude and location.

To develop event waveform extraction techniques, two tasks are being performed as follows:

- Extract long-period bodywaves from edited single sensor three component data and from array data.
- Cascade several methods of long-period event waveform estimations to optimize the extraction of weak signals.

To develop interactive graphics signal analysis capability, the following three tasks are being performed:

- Standardize seismic processing functions for performing discrimination analysis.
- Extend the Interactive Seismic Processing System (ISPS) by developing a seismic programming language to generate displays, plots, and tables from data and information files stored on the disk; and which can perform simple analysis functions on this data.
- Develop software for transfering data to a mass store.

The final program task is to derive accurate transmission path corrections and source parameters from long-period data. This is broken down into three tasks as follows:

- Use newly developed and existing software for spectral analysis corrected for instrument response, path attenuation, and dispersion; also compare these to theoretical spectra and radiation patterns derived from the best fit source model as a means of estimating the source parameters associated with an event.
- Form a suitable data base with long-period waveforms measured at a large number of stations providing adequate azimuthal coverage of the event.

SECTION II
ILPA AND SRO EVALUATION

A. CURRENT STATUS

For both the ILPA and SRO data evaluation tasks, work was concentrated on processing a suitable data base and on utilizing software created to adequately estimate the capability of each station and of combined stations to detect and identify events from regions of surveillance interest. Events reported by the Norwegian Seismic Array (NORSAR) were regionalized using the system given by Flynn and Engdahl (1965). Events, from those regions in Eurasia with one hundred or more events reported between 22 December 1975 and 30 September 1976, were put into the data base. A NEIS event list is needed to proceed beyond this date. Routine signal processing and analysis continued this quarter. The routine processing consists of quality checking the data, of a visual detection decision, and of long-period data measurements of the surface wave magnitude of events detected at periods of twenty, thirty, and forty seconds. The magnitudes were measured by an automatic magnitude measurement program. The program was compared with analyst magnitude measurements and demonstrated correspondence to $\pm$ 0.05 magnitude units in all cases tested. The noise analysis programs used in the last contract period were rechecked and found to be good. As a result of TS conversion, an error was introduced into the SROGEN program. We are now attempting to find and correct this problem.

B. FUTURE PLANS

During the next quarter, work will be concentrated on the following areas:

- Routine signal processing and analysis.
- Noise analysis.

In starting the analysis of short-period and long-period noise, our goals are as follows:

- Edit noise samples and beamform ILPA noise samples.
- Maintain and create any new programs necessary for the noise analysis.
- Begin to compile noise analysis results.

SECTION III
DETECTION METHODS

A. CURRENT STATUS

The frequency dependent detector design and evaluation have been completed. The report is now under preparation. Tests of the phase detector indicated errors less than 4 seconds for timing of the onset of long-period surface waves at signal-to-noise ratios greater than 0 dB. Last year, an attempt was made to apply an adaptive beamforming algorithm to the detection of weak short-period signals. The results indicated marginal gains of one to two dB for high signal-to-noise ratio (S/N) events and zero gain for weak signals. To possibly improve on these results, a new research version of the adaptive beamforming (ABF) program was written in FORTRAN for the TS system. By modifying this program and testing it on data, new ABF algorithms are now being tested to determine their effectiveness in detecting weak signals. Other possible applications are first motion detection, coda suppression, later phase detection, and multiple event detection. Detection association processing is in the planning stage. Network capability evaluation procedures are being developed for more realistic evaluations.

B. FUTURE PLANS

The following developments are expected in the next quarter:

- Complete the report on the frequency dependent detector.
- Complete evaluation of the phase detector timing of the onset of long-period surface waves and begin software development of a short-period detector.

- Complete the development of new ABF algorithms.
- Develop improved detection association processor (DAP) software and test modifications with simulated network detection bulletins.
- Maintain the network capability and evaluation software and continue runs designed to remove bias in estimations of network capability.

SECTION IV
EXTRACTION OF EVENT WAVEFORMS

A. CURRENT STATUS

An adaptive filter was developed to extract long-period bodywave phases based on their expected polarization. Suitable bandpass filters for detecting bodywave phases are now being developed. Tests of three methods of extracting weak surface waves were completed. These were the Wiener filter, three component adaptive filter (TCA), and matched filter. These processes were cascaded to provide gains over any one of the processes. The results were most favorable for cascading the Wiener filter and the TCA filter. Processing of events from the Kurile Islands recorded at Guam SRO was begun. A detection log was developed to evaluate improvements in the detection threshold.

B. FUTURE PLANS

In the next quarter, the new processor for the extraction of bodywaves will be tested. The polarization orientation parameter, which is allowed to change as a function of frequency, provides useful regionalization measurements for the design of advanced polarization filters. The processing of surface waves, using the cascaded Wiener-TCA filter, should be completed during the next quarter.

SECTION V
INTERACTIVE SEISMIC PROCESSING

A. CURRENT STATUS

During the past quarter, an improved interactive seismic processing system was developed on the PDP-15 computer. It supports the preparation of standard seismic processing functions to be used for routine seismic event analysis. The system is based on the existing Interactive Seismic Processing System (ISPS) and supports the following features:

- Standard processing functions, developed and tested using the present fully interactive version of the ISPS, can be programmed and set with the desired constraints and automation required for standard processing.
- The definition of functions by a user can range from a fully interactive to a fully automatic mode of operation.
- Accepted standard processing functions are automatically stored for convenient future use.
- The programmable mode of operation enables the use of all the general features now offered by the ISPS.

B. FUTURE PLANS

The new extended ISPS system will be applied to designing and testing new standard processing functions. Work will begin on the development of a high level seismic programming language to complete the development of the programmable ISPS system.

It is expected that all the design specifications for KSRS data transfer software will be completed. These will include long-period data restrictions. In the future, logs will be kept of the status of the Data Computer to determine the fraction of down time.

SECTION VI

SOURCE PARAMETERS FROM LONG-PERIOD SURFACE WAVE DATA

A. CURRENT STATUS

The program which corrects surface wave spectra for geometric spreading, attenuation, and instrument response was updated with new Very Long-Period Experiment (VLPE) and SRO instrument response corrections (for 1975 and 1976). The second approach to the formulation of the combined source problem was implemented. Software was written to transfer Special Data Collection System (SDCS) data to disk files for processing by the ISPS on the PDP-15 computer. A program was written to plot observed Long-period Rayleigh wave (LR), Long-period Love wave (LQ), and LQ/LR for all stations of a particular event.

Processing was completed of selected events using the ISPS with the exception of newly acquired events added to the event list. Observed surface wave spectra and travel path group velocity curves were obtained. Observed surface wave spectra were corrected for instrument response and travel path effects with the exception of SDCS data. The corrected spectra were ready to be used for the estimations of travel path attenuation and source parameters. The computation of the amplification factors ($m\mu$/cc values) for the SDCS stations was completed, and two instrument response curves (one of station FN-WV and one of the other stations) were obtained. These are necessary for the appropriate correction of the observed spectra at SDCS stations.

The examination of the event-station travel path group velocity curves has been continued.

- For most paths, multipathing existed, especially for periods below about 30 seconds.
- For predominantly oceanic paths, the group velocity followed the standard oceanic curve.
- Some paths in the eastern U.S. showed reversed dispersion occurring around 55 to 60 seconds for both Rayleigh and Love waves.
- The group velocity curve fluctuated from event to event. This was probably due to the inaccuracy in the event location and origin time.

The layered half-space earth models for the presumed eastern Kazakh test site (EKZ) and the presumed Peaceful Nuclear Explosion site (PNE) events were constructed, and the Harkrider's medium response solutions were obtained. Two earth models were constructed. One was the north Caspian Basin which was appropriate for the selected PNE events, and the other was the Balkhash-Chingiz foldbelt which was appropriate for the EKZ events.

The LQ/LR ratios were computed, and the amplitude spectra of LR, LQ, and LQ/LR were plotted. Azimuthal variation of the observed spectra was noticeable. The Love wave (LQ) signals were clearly observed at most stations.

Source spectra from the Nevada Test Site (NTS) and EKZ indicated induced earthquakes associated with the explosions. NTS induced earthquakes are nearly vertical strike-slip with a relative strength of 0.5 to 1.0. An EKZ induced earthquake was dip-slip with a relative strength of 0.56.

B. FUTURE PLANS

A spectral correction program will be written to correct observed spectra at SDCS stations for travel path and instrument response.

The examination of the event-station travel path group velocity curves will be continued. Relative excitation of the Love waves from a suite of NTS events will be investigated. The estimation of the surface wave energy attenuation coefficients along various travel paths will be started. The source parameter estimation of the selected events will be continued.

SECTION VII
REFERENCES

Flynn, E. A., and E. R. Engdahl, 1965, A Proposed Basis for Geographical and Seismic Regionalization; Reviews of Geophysics, Vol. 3, No. 1, p. 123-149.